Management Report

AN INTEGRATED ECOLOGICAL APPROACH
TO THE MANAGEMENT OF
EUROPEAN WILD BOAR (*SUS SCROFA*)
IN GREAT SMOKY MOUNTAINS NATIONAL PARK
MANAGEMENT REPORT NO. 3

NATIONAL PARK SERVICE
SOUTHEAST REGIONAL
UPLANDS FIELD RESEARCH LABORATORY
GREAT SMOKY MOUNTAINS
NATIONAL PARK

NATIONAL PARK SERVICE
Department of the Interior

AN INTEGRATED ECOLOGICAL APPROACH

TO THE MANAGEMENT OF

EUROPEAN WILD BOAR (*SUS SCROFA*)

IN GREAT SMOKY MOUNTAINS NATIONAL PARK

MANAGEMENT REPORT NO. 3

by

Dr. Susan P. Bratton
Uplands Field Research Laboratory
Great Smoky Mountains National Park

Note to the reader:

Although this paper is presented as No. 3 in the Management Report Series of the Uplands Field Research Laboratory, it was originally presented to the Park Service in 1974, before the Management Report Series was started. Because the Uplands Field Research Laboratory is continuing to receive requests for the paper, we have reprinted it. Since Park management policies have changed in the last year, some of the material presented here is already out of date, but the general presentation and bibliography should be useful to reseachers, students and managers interested in wild hogs. The bibliography has been expanded to include more recent items and papers not discussed in the original report.

An Integrated Ecological Approach to the Management of the European Wild Boar (Sus Scrofa) in Great Smoky Mountains National Park

Susan Power Bratton
Cornell University
Ithaca, New York
April 8th, 1974

Since the Park Service Hog Control Program began in 1959, several hundred hogs have been killed or removed from the Great Smoky Mountains National Park. This program has, however, failed to limit the growth of the hog population. During the period the present control program has been in effect, the number of wild hogs in the Park has not only increased, but the hogs have extended their range to include well over half the Park. The Park Service should, therefore, review their policies concerning the elimination of this exotic species and consider modifying both the control techniques employed and the type of scientific study presently encouraged.

I. The reasons management is necessary.

A. Damage to the Park

The need for a more intensive management program is related to a multitude of ecological problems presented by hogs. First of all, the proliferation of wild swine throughout much of the Park has been extremely disruptive to certain elements of the native flora and fauna.

Among the damages inflicted by wild boar are:

1. The destruction of wild flower areas.

Hogs rely heavily on underground parts of plants and the resulting rooting disturbance is removing the herbaceous understory of certain forest types. Beech forest understory may be reduced to 2 percent of its normal cover.In the Western half of the Park, the carpets of spring beauties (Claytonia Virginica),

fawn lily (Erythronium Americanum), and wake robin (Trilium Erectum) have been greatly reduced in both cover and the number of blooming plants (Bratton 1974). Some of the sites most famous for these floral displays, such as the "rich, wooded slopes...along the Appalachian Trail between Newfound Gap and Indian Gap" recommended in Great Smoky Mountains Wildflowers, a popular guide by Campbell, Hutson and Sharp (1970), are still free of hogs. With the present range extensions and population increases of the wild boar, however, this situation will eventually change. The movement of the hogs into the forests near Route 441 and the Clingman's Dome road will make their rooting activities far more noticable to park visitors and may create public relations problems. Damage to well known wildflower sites will probably include some of those usually visited by the Wildflower Pilgrimage.

2. Reduction of individual plant populations.

The hogs actually eat certain species of wild flowers. The Turk's cap lily (Lilium superbum), for instance, has edible bulbs. "A large colony of this beautiful lily", which according to Great Smoky Mountains Wildflowers, "appears along the Appalachian Trail between Clingman's Dome and Siler's Bald" was selectively rooted for Turk's cap bulbs in the summer of 1973, and most of the plants were removed. The recovery potential of this species is unknown.

All together about a third of the herbaceous species listed in Great Smoky Mountains Wildflowers, have already been observed to be eaten, uprooted or trampled by hogs. (Bratton, 1974). The list of affected species may be expected to grow as the hog population expands and observation of hog rooting continues. There are at least 95 genera mentioned as hog food plants in European studies which are also found in Great Smoky Mountains National Park (Bratton, 1974).

3. Damage to tree roots and seedlings.

The exposure and death of innumerable fine roots of woody plants, accompanies the overturn of the soil surface during hog rooting. Field observation indicates that certain woody roots, such as those of pitch pine (Pinus rigida)

and tulip tree (Lireodendron tulipiferia), (Conley et al., 1973) are eaten. In other cases, such as that of beech (Fagus grandifolia) there is no evidence that the cambium is stripped from the larger roots. Small roots are sometimes eaten incidentally but a majority of the superfical fine roots are left to dry on the soil surface.

The implications of this sort of root system damage for tree growth and reproduction have apparently never been investigated in the United States. European studies on both wild and domestic swine indicate selective damage to different tree species. In one experiment with domestic hogs Bjerke (1959, cited in Forestry Abstracts) found that pigs would bark oak and elm, whereas both young and old beech were usually left alone. After a year of hog occupation, in the forest in question "...there were 20-80 Beech seedlings / sq. m. in autumn 1959 compared with 1 seedling / sq. m. before." Feeding experiments indicated a preference for oak, elm and alder bark, followed by ash and hornbeam. Hazel, birch and maple were rarely eaten; beech was completely untouched. These results are in agreement with a European theory that intense grazing and rooting by domestic swine over a period of several hundred years, has altered the species composition of many European forests in favor of beech. (Bjerke 1957, cited in Forestry Abstracts)

Wild boar should have a similar impact although their density per hectare is usually less. In the Great Smoky Mountains, a large population of wild boar may, over a long period of time, change the species composition in some types of forests. In high elevation hardwood forests there is already a noticeable increase in beech root sprouts after hog rooting. Some of the most heavily damaged sites have the most sprouts.

4. Damage to the grass balds.

The hogs break and roll the turf under the mountain oat grass (Danthonia compressa), causing soil erosion and a change in the local successional pattern. Weedy forbs such as Potentilla and Rumex usually invade the scars because the

grasses are slow to recolonize. Hogs also root under shrubs and in patches of *Rubus*. These sites are reoccupied by *Potentilla* and semi-shade plants like *Stachyus clingmannii*.

5. Soil erosion.

In the most heavily rooted sites the organic surface horizons of the soil are throughly mixed with mineral soil from lower layers. Deprived of the protective cover of leaf litter, these areas suffer sheet erosion and compaction. There is little doubt that the sediment load in some creeks is increased. The hogs' habit of rooting along stream banks and digging wallows in springs and small creeks serves to magnify the problem. The impact of hogs on the stream biota is unresearched, but should be of great interest, particularly to trout fishermen.

The changes in the leaf litter and soil surface structure are a form of habitat destruction which also affects the smaller native terrestrial animals. Of notable importance is the adverse impact on the herpetofauna, particularly salamanders.

6. Predation on native animals.

Hogs consume a wide variety of animal foods. They eat large quantities of invertebrates, some of which, for instance, earthworms (Tanda 1957, Briedermann 1968, Scott 1973) and ants (Tanda 1957), are usually assumed to be beneficial to the forest ecosystem. Other invertebrate food items are snails, mussels and crayfish (Boback 1955, Sludskii 1956).

Eurasian studies indicate mice and other small rodents are eaten when they are available. Briedermann (1968) found 143 mice representing two families, Microtidae and Muridae and three genera *Apodemus*, *Microtus* and *Clethrinonomys*, in 102 of 181 wild boar stomachs, he investigated. He also found two moles (*Talpa europaea*). Bromlei (1964) and Sablina (1955) list moles and mice as major animal components of the hogs diet. Sablina (1955) notes that wild boar not only eat

small rodents but invade their nests, devour their young and break into their winter stores. The latter type of behavior has important consequences for squirrels and chipmunks in the Great Smoky Mountains.

Hogs sometimes attack larger mammals. An excessive population of wild boar is therefore, considered bad management in European hunting preserves. "It is well known, that in a Revier with many wild boar, the hare hunting deteriorates" (Boback, 1955). This is largely due to the consumption of young hares and rabbits (Haber 1961, Snethlage 1967). According to Boback (1955) hogs will occasionally kill fawns. Usually, however, big game is sick or injured before it is attacked by wild boar.

The same principles of management also apply to ground nesting birds since hogs eat both their eggs and their young. (Sablina 1955, Haber 1961). Boback (1955) mentions, for instance, that "An increase in wild swine initiates a decrease in the Capercaillie." (or Auerhahn, Tetrao urogallus) and that a high density of wild boar is simply not compatable with maintenance of a huntable population of this ground nesting member of the grouse family, similar to our wild turkey in size. In Europe the boar also disturb red grouse and pheasant.

In the Great Smokies the birds most likely to be affected by wild boar include both ruffed grouse and wild turkeys. Turkeys are not very common in the Park (Stupka 1963) and are extremely sensitive to disruption during nesting. Although as Stegeman (1938) points out, grouse and turkeys may benefit from increased food availability through the insects turned up by hogs, the beneficial effects of hogs are probably negatively correlated with the number of pigs in an area. The larger the populationof hogs, the more certain the destruction of nests.

Aside from birds and mammals the hogs eat lower vertebrates - fish, amphibians and reptiles. Both snakes and salamanders have been found in the stomach contents of hogs shot in Great Smoky Mountains National Park. (Scott 1973)

Briedermann (1968) found 6 blindworms (Anguis Vragilis), 2 fence lizards (Lacerta agilis), 3 water snakes (Natrix natrix) and 24 assorted frogs in the 181 stomachs he examined. Sablina (1955) believes that wild boar actively seek out snakes in the brush and that the boar are not afraid of being bitten. This agrees with the observations of the local people in the Great Smokies who believe both wild and domestic hogs eat all types of snakes, including pit vipers. Sablina (1955) notes that the number of snakes in Belowesh Preserve in Poland is severly reduced in years when the boar population expands.

The Great Smoky Mountains National Park has an interesting and well developed woodland herpetofauna and has an international reputation for its diversity of salamanders. A large population of wild hogs is not compatible with maintaining many of these native reptile and amphibian populations at their normal levels. Habitat destruction may prevent locally exterminated species from reestablishing.

7. Competition with native species.

Perhaps the greatest competitor of the boar is the black bear. Recent studies of bear (Beeman 1971) and boar (Matschke 1967, Henry and Conley 1972, and Scott 1973) have shown the importance of mast to both species in the fall. The wild boar also consume herbs, grasses, berries and carrion which might otherwise be available to bear. Black bear prey on young hogs, but this probably does not compensate for the mast lost to hogs in the fall, especially when the hog population is large. Boar may avoid bears as predators but Reed King, a local hunter, reported seeing a large boar drive a young bear away from an oak stand with a good crop of acorns.

Several other species, including deer, turkeys, squirrels and chipmunks, also compete for mast. Deer and boar both graze sedges, grasses and herbs along the trails and on the grass balds. The hogs also utilize animal foods, such as insects, crayfish, amphibians, small mammals, and birds eggs which would otherwise be available to skunks, opossums, raccoons, foxes and bobcats.

One should note that the European wild boar has many competitors in its native range and that it has coexisted with several species of deer and bear for thousands of years. Sablina (1955) points out that, of the plant species utilized by both deer and hogs in Europe, in only a few cases are they consumed by both species at the same time of year or are the same parts eaten. The brown bear (Ursus arcticus) is well adapted to competition from wild boar and turns to preying on hogs when the mast crop fails (Rakov, 1966). Even, in its native range, however, an over population of boar is detrimental to other species and a well managed preserve keeps the wild boar population low.

There is in fact, no reason why a small population of wild boar could not coexist with the larger mammals in the National Park. At Tellico Wildlife Management area deer, boar and bear live together and each species maintains a huntable population. A substantial portion of the hog population is killed by hunters each year, however.

The apparent recent drop in the bear population in the Great Smokies has been attributed to competition with hogs - a logical accusation. The hog population must be near carrying capacity in the Western half of the Park and the hogs are certain to dominate a majority of the food available. Local hunters estimate hogs outnumber the bears by more than 20 to 1 around Cades Cove. (Reed King and friends, personal communications). The continued uncontrolled growth of the wild hog population is placing increasing pressure on the native species with which it competes for food. The harm to the bear population alone, provides a sound reason for monitoring the hog population and artifically inhibiting its growth.

It should, in summary be obvious that wild hogs are a ubiquitous problem. They are affecting every major plant community and many of the best known animal species in the Park.

Population Dynamics.

The second major reason, after that of ecological damage, for instituting artifical control, concerns the dynamics of the boar population itself. Obviously food is available in the Park and the hog population is expanding. The rate of population growth in the Park indicates the wild boar is no more limited by environmental factors than it is in its native range. The question then becomes which factors are presently limiting hog population growth and, if the Park Service does not institute a more intensive management program, what will ultimately limit the hog population?

The potential limiting factors include:

1. Predation.

Throughout its native range the wild boar has a variety of predators. In the Amur territory of the Soviet Union, Rakov (1970) found the brown bear (Ursus arcticus) was responsible for 21.8 percent of all hog mortalities, the wolf was responsible for 6.9 percent, the tiger was responsible for 5.0 percent, the lynx for 1.7 percent and the leopard for .6 percent. All together predators accounted for 36.0 percent of the animals found dead and 55.8 percent of these were piglets. In Belowesh preserve, by contrast, the wolf is the most important predator of hogs and hogs are the single most important species in the wolves diet. The numbers of hogs killed by wolves alone may exceed 10 percent of the total estimated hog population and can constitute over 25 percent of the wolves diet (Gaurin 1954).

Of the species mentioned above, only the lynx has an ecological equivalent in the Great Smoky Mountains. Bobcats (Lynx rufus) function as the European lynx does by hunting and killing piglets. The black bear, on the other hand, is a smaller, less aggressive animal than the brown bear and therefore is a less effective predator. The wolf has been extirpated from the Park and the only native big cat, the mountain lion, is either extinct or very rare in the Southern

Appalachians (Linzey and Linzey 1971). The wild boar in the Park is thus free from much of the predator pressure to which it was subject in the Old World.

2. Weather conditions.

In some areas, a second major cause of mortality is freezing, which is usually associated with starvation. (Rakov 1970). A mean snow depth of 50 cm. is, in fact, usually considered to be the major limitation of the wild boar on the Northern border of their range in Europe (Heptner and Naumov 1966). A frozen soil surface prevents rooting and deep snow inhibits the movements of hogs. Bad weather in combination with a poor mast year may reduce the hog population to extremely low levels. In Belowesh Preserve, drops in the hog population of 50 percent annually may be attributed to frozen soil and bad weather. Cabon (1958) and Kozlo (1970) describe in detail a combination of hard winters and poor mast crops which dropped the population from 1166 in 1951 to 176 by 1956. Rakov (1970) lists freezing as the most important cause of death in the Amur territory. Severe winter weather was blamed for 49.3 percent of the total mortalities. In Rakov's study there were 524 deaths from all causes in January and February whereas there were only 49 from May to September.

The climate of the Smokies is not cold enough to freeze the soil solidly for long periods, and severe snow storms are rare at lower elevations. Weather alone should not consistantly limit hog population growth, although a bad storm during farrowing in February or March may kill a large number of piglets.

3. Disease.

The European wild boar is susceptible to a number of contageous diseases of which hog cholera is one of the most devastating. The chances of disease outbreaks increase as the density of the population increases. The hogs, of course, also become more liable to parasites and disease when they are short of food and in a weakened conditions.

Disease outbreaks are a common management problem in Europe. Spiecher (1969) describes a hog cholera epidemic in Germany which reduced many of the herds in shooting preserves to 10 percent of their original number. The disease is usually contracted from domestic hogs or infected supplementary feed. German law requires the "Vetinary Police" be informed of any cases because the wild boar frequently manage to reinfect domestic stock.

The impact of disease in an overpopulated area can be very dramatic. In Belowesh preserve an estimated population of 2000 hogs in the spring of 1964 was reduced to 550 head by the end of the year because of an epidemic which began in June (Kozlo 1970). Note, however, that by 1966 the population had returned to a stable size of 1250. Though a disease outbreak may relieve overcrowding, a well established hog population will return to a healthy level within two or three years. In a small preserve, on the other hand, a herd may be exterminated due to health regulations.

In 1973, there was no evidence of high disease mortality in the Great Smoky Mountains. The wild hogs throughout the whole Southern Appalachian area were apparently free of hog cholera. Even though the likelihood of disease outbreaks will increase as the hog population increases, epidemics should not be looked to as the eventual solution to the "hog problem". First, the wild boar is well entrenched in the National Park and the herds are scattered throughout many small watersheds. Therefore, not all the hogs would be infected and the population should recover quickly. Second, a bad outbreak of hog cholera would create immediate management and public relations problems. The Park Service would have to call in Federal disease control personnel, and would have to shoot infected animals and dispose of the bodies. The Department of Agriculture might require that certain areas be quarantined and that disinfection procedures be instituted. Both of these procedures are in conflict with the aesthetic experience a visitor expects

in a National Park. Third, the health of the wild boar in the Park is related to the health of other wildlife and to that of domestic stock on neighboring farms. Aside from parasites like trichinae, hogs may contract and spread contagious diseaseslike rabies or hoof and mouth disease. (For general references see Wetzel and Ries 1962, Weidemuller 1964, Kerschagl 1965, and Schulze 1965)

Disease would not force the hog population to a consistantly low level but instead would result in fluctuations and continued damage to the native biota of the Park. Epidemics have undesirable side effects and should be avoided by careful population management.

4. Food.

Food availability is always an ultimate limit on population growth and in the long run will determine the carrying capacity of different habitats for hogs. Allowing the hogs to reach carrying capacity is the least desirable way of limiting the population because it will have the most undesirable impact on other species. Herds of starving hogs, gobbling up every acorn, salamander, bird's egg, and flower bulb, can hardly be considered an ideal solution to hog population growth. Even if the Park Service decides they cannot possibly hope to exterminate the hogs, the population should be kept well below the carrying capacity, as determined by food resources, in order to alleviate the effects of competition and predation on other species. A population limited by food will cause extensive rooting damage which will probably include areas which are low in food resources and of marginal value to the hogs.

5. Hunting by man.

Human hunting pressure is today one of the most important controls on European wild boar throughout the agricultural regions of its native range. Hunting has extripated the wild boar from many areas including Great Britain and the Nile Valley and has substantially reduced the boar population throughout

most of Western Europe (Niethammer 1963). Range changes in recent years have been closely related to hunting by man. (Heptner and Naumov 1966).

There are numerous examples in the literature of the effects of differential hunting pressure. Vereshchagin (1967) states that "Hunting was the chief operative factor in the disappearance of boar from (ancient) Christian Armenia, a fact that is pointed up by the contemporary existence of a large boar population in considerably drier regions of Iran and Turkey..." where the Moslem residents do not eat pork. A more recent example concerns a steady increase in the wild boar populations of Germany and Eastern Europe during and after the Second World War. This has been attributed to lack of hunting and controls on the ownership of fire arms immediately after the War. Because of agricultural damage, the populations had to be strongly reduced. In Germany, for instance, 8784 hogs were shot in 1938-1939, and 21,157 were shot in 1957-1958 (Müller-Using 1960). In Poland, where the wild boar population was 46,500 in 1954 and 50,000 in 1955, the state game managers decided to reduce the population to 30,000 to curb damage to crops. Through intensive hunting they lowered the population to 40,000 by 1959 (Haber 1961).

In the Great Smoky Mountains there are two types of human predators on wild boar - one is the ranger who participates in the Park Control Program and the other is the illegal hunter who brings his gun and dogs inside the Park boundary. The rate at which the Park Service has removed hogs is well documented but the exact number of hogs removed by poachers is impossible to estimate with any degree of confidence. According to Reed King, a local farmer who was arrested for hunting in the Park, there were about 80 hogs removed from the Park by residents of Wear Valley and Townsend in 1973. The most active poachers supposedly kill more than 20 hogs apiece a year. One poacher is reported to have killed 26 or 27 wild hogs in the Park that year. This information indicates that the count of illegally taken pigs is certainly over 100 per year and may be in excess of 300. Pig hunting

in the Park apparently became popular in Tennessee about 1959, the same year the Park Control Program began, and accelerated through the 1960's.

The large number of hogs in the Park encourages illegal hunting and is related to poaching of other species. The hunters know that the Park Service is trying to reduce the hog population and they are perfectly aware the Park Service has failed in this attempt. As far as the hunters are concerned they are doing the Park a favor by shooting hogs, and they therefore, can easily rationalize killing a deer or bear. The large hog population has also renewed interest by the hunters' lobby in creating a legal hunting season in the Park. Their arguments are becoming difficult to ignore, as the hogs take over more and more of the Park.

A recent crackdown on poaching, conducted by rangers in the summer of 1973, may change the importance of illegal hunting as a control on hog populations. The dilemma is simply - if the Park moves to restrict poaching without increasing its own control program the hog population will expand even faster; if the Park Service does not inhibit poaching more bears will be shot. An intensification of poacher patrols should therefore parallel on intensification of hog control. It is quite possible that poachers have exerted more of a control over the hog population than the Park Service has. During the one year period of Fox's (1972) study, 139 hogs were "officially" removed. Poachers probably took at least that many and may have killed twice that number.

Legal and illegal hunting and trapping have together slowed the colonization of the Great Smoky Mountains by hogs, but they have hardly stopped it. Since the actual number of hogs killed by man is far greater than the number listed in the Park records, the Park Service must not only increase the number killed relative to the number they already take but they have to relieve the poachers of their present share.

The swine in the National Park will never be greatly limited by native predators and weather conditions. The choice is therefore between starvation and

disease or hunting by man. Starvation is undesirable because a large, collapsing population will heavily root all available feeding sites and compete heavily with other animal species for food. The population fluctuations which a strictly food or disease limited population undergoes would not allow sufficient time for the disturbed plant and animal species to recover. Control by man is necessary just to stabilize the hog population at a moderate level. Considering the number of hogs already removed by hunting, reducing the population until it has a negligible ecological impact will require very intensive management. European work has shown that populations can be controlled and reduced by hunting.

II. Establishing control over the hog population.

A. Reproductive potential and carrying capacity.

Before beginning a control program, the managers have to know how many hogs have to be removed to stabilize or to reduce the population. The answer is quite complex and is a function of the carrying capacity of the Park and the reproductive potential of the hogs.

Hogs have large litters and can easily replace individuals lost through predation or disease. In Belowesh Preserve, annual increases in population have been as high as 178 percent (from 478 to 1325 hogs). From 1946 to 1966 over half the positive annual changes in population were over 40 percent. (Kozlo 1970). Similar rates have been found in the crimea where an introduced herd of 35 individuals expanded to 2100 over a period of 10 years (Kormilitsin and Dulitskii 1972).

Reduction by hunting is somewhat like reduction by disease - if the pressure is removed and food is available the population will recover in 2 or 3 years. The high resistance of the wild boar to hunting is well illustrated by population data from a Polish control program (Haber 1961). In 1954 they had 46,500 hogs and removed 11,000 (24 percent). The next year they had 50,000 hogs.

In 1955 they removed 40 percent and the population still increased by 1500. In 1956 they killed 33 percent and the population fell by 10,000. In 1958 they removed close to 50 percent and the population remained stable. These data indicate that not only does a high percentage of the population have to be killed in order to reduce it, but that the percentage removal effective in stabilizing the population varies from year to year with the mast crop and weather conditions. Also, as the population is reduced below carrying capacity, and food limitation becomes less important the reproductive potential increases, requiring a greater percentage of the population be removed each year.

These principles are well understood by European game managers who cull their herds strongly. Hennig (1963) recommends that at least 50 percent of the yearling class be removed annually and, that in years of good reproduction, 80 percent should be killed. Only in cases where an increase in the total population size is desired or there is an exceptionally poor year for reproduction should more than 50 percent of the yearlings be allowed to survive. The Germans also shoot a number of mature animals from the older age classes (6 to 10 years). These usually constitute about 20 percent of the animals of reproductive age. Under Henning's scheme removing about 50 percent of the total population is required to stabilize the age distribution.

At Tellico Wildlife Management Area, where the age classes removed are not so strictly selected, Richard Conley (personal communication) reported that about 25 percent of the estimated population can be removed by hunters each fall without seriously inhibiting the reproduction of the population or reducing it below its carrying capacity. For real control in Great Smoky Mountains National Park, therefore, the percent of the population removed annually should be at least 25 percent and if reduction is desired, it should exceed 50 percent.

In order to apply this information to the Great Smokies, however, we

need to know how many hogs there are in the National Park. The standing estimate in the spring of 1973 was 500 animals. This estimate was originally made in 1959 (Linzey and Linzey 1971). Mike Meyers suggested during the summer of 1973 that the estimate be increased to 800 individuals. Unfortunately, neither of these estimates is from quantitative data. Fox (1972) believed 500 to be an underestimate and there is evidence to support his suggestion. First of all this is a lower density per acre than reported for near by Tellico Wildlife Management Area. Tellico is about a third of the size of the area presently occupied by hogs in the National Park and has 600 to 800 wild boar (Richard Conley, personal communication). If the density of hogs in the Park were equal to that of Tellico the population would be between 1800 and 2400. These figures may appear high but in other areas of deciduous forest, such as Belowesh Preserve, there may be 20 hogs per 1000 ha. (Kozlo 1970). The mean for some large European preserves is 10 to 14 per 1000 ha. and some Far Eastern habitats may support 30 per 1000 ha. (Heptner and Naumov 1966). Some less favorable habitats support fewer. The Kaukaschen Nature Preserve has 4 to 8 per 1000 ha. (Donaurov and Teplov 1938). In agricultural areas where overpopulation instigates damage to crops, recommended densities vary from 2 to 10 per 1000 ha. (Boback 1955) One should recognize that maintaining a consistantly low density of 6 per 1000 ha. in most deciduous forest habitats requires intensive management through hunting.

Now suppose 500 hogs was an accurate estimate in 1959, has the Park Service removed enough hogs to maintain this level? If 25 percent removal on the average would stabilize the population, the total number of hogs removed would have to be 125 per year or 1750 over the past 14 years. If 50 percent removal is necessary to stabilize the population, the total number of hogs removed would have to be 250 hogs a year or 3500 hogs over the past 14 years. Since the Park Service only removed 522 hogs from 1959-72 (Fox 1972), the official Control Program has not

even met the more conservative figure of 1750.

Looking at the situation for 1974 and 1975 one can estimate how many hogs will have to be removed to merely stabilize the population. If, as Mike Meyers suggests, there are 800 hogs in the Park, and poachers kill 300, the Park Service needs to remove 100 animals. If poaching is negligible, the Park Service has to remove 400.- If there are 1800 animals in the Park, the Park Service needs to remove 600 to 900 hogs. If there are 2400 animals in the Park, the Control Program should take from 900 to 1200 hogs.

In lieu of a dependable population estimate, a conservative control program should aim high rather than low. Instead of arbitrarily deciding the total population is 800 hogs, the Park Service should decide to remove 800 hogs next year. Since this is about the number taken by the whole control program over the past decade and a half, the techniques used for control will have to be revised. An efficient program, which can be maintained through the years with a minimum of effort, needs to be established immediately before the problem gets any worse. Furthermore, after the population has been effectively cut back, plans should be made to maintain hunting pressure on the population since the hogs are able to recover extremely quickly.

B. Estimating populations.

The more practical aspects of the hog control program can benefit greatly from ecological research so the two must be pursued together. The first task is to set up a program for censusing the hog population. In Europe this is often done in the winter by counting tracks in the snow. The census takers walk regular transects in selected sections of representative habitats. There are numerous other standard wildlife censusing techniques that can be tried until a suitable one is found. For the purposes of hog control, fairly exact estimates are not as necessary as evaluating relative yearly increases or decreases.

In conjunction with the census, information on hog movement into new areas should be carefully recorded. At present no data is available for the Park, which shows exactly when the hogs invaded the different watersheds and various ridgetops, they now occupy. This type of data is easy to collect and has multiple uses. Quantification of variations in hog population density in areas with different histories of occupation can provide insight into the hogs' pattern of resource utilization and the recovery capabilities of some of their food plants. One can also determine whether the population is remaining constant and occupying new territory because over grazing is reducing the available food in its old range or if range extension is paralleled by population expansion. Fadeev (1973) indicates that when wild boar are expanding their range the density of hogs per 1000 ha. influences the likelihood of movement, the pattern of habitat occupation, the rate of reproduction, and the resistance of the population to unfavorable climatic conditions.

Since a control program is useless if the population continues to grow from year to year, a census is actually the scoreboard which allows management personnel to assess the success of the control program and to adjust trapping intensity to population fluctuations. Census data may also be used to construct a model which will predict population growth under a variety of circumstances. The most useful variables to quantify are trapping success, mortality from predators, disease and poachers, the quality of the mast crop and the occurrence of extreme weather conditions. The census data from the trapping records can provide the number of offspring per sow each year, the reproductive success of different age classes and the age structure of the population. By maintaining detailed records on environmental variables and population structure, it should eventually be possible to determine the impact of each factor on the hogs reproduction from year to year. Multivariate techniques of analysis may be used to determine the importance of individual variables and the presence of synergistic effects.

The standard model for determining R_o, the overall reproductive rate for the population is shown below.

Age Class	Number of animals (or females) N_x	Age Specific Survival l_x	Age Specific Natality m_x	l_x m_x
0	130	1.0	0	.00
1	---	---	0	.00
2	26	.20	.65	.13
3	29	.22	1.55	.35
4-5	16	.12	2.12	.26
6-7	11	.08	2.55	.22
8-10	3	.02	2.13	.04
				1.00

(Data taken from Sablina 1955, and adjusted so that the population is stable.)

Changes in N_x, l_x and m_x are all functions of environmental variables. If there were an outbreak of hog cholera, for instance, N_x and l_x would drop drastically. The magnitude of the change would be greater for younger age classes, because young animals are more susceptible to the disease. If the mast crop failed m_x should change. In Belowesh, for example, when the mast crop is good, almost all sows produce young and the average number born is 5.8 per sow with young. When there is no mast only the older age classes reproduce and the average number of piglets per sow with young is 3.1. Even in a good year the number of embryos or young per female is higher in the older age classes. In a good year 30.7% of the two year old sows shot during the winter were pregnant as opposed to 78.1 per cent of the six and seven year olds. The number of embryos per sow was 4.2 for the two year olds and 6.6 for six to seven year olds. (Sablina 1955). Thus m_x could actually be treated as a matrix.

MAST YEAR

Age Class	Good				Poor
0	0	0	0	0	0
1	m_{11}	0	0	0	0
2	m_{21}	m_{22}	m_{23}	m_{24}	0
3	m_{31}	m_{32}	m_{33}	m_{34}	m_{35}
4	m_{41}	m_{42}	m_{43}	m_{44}	m_{45}
	and so forth.				

The same is true of l_x which is a function of hunting pressure, predation, disease and food availability. Both l_x and m_x are density dependent and are likely to increase as the density of the population decreases. A discrete value for R_o for any particular year requires a series of vectors which may be multiplied to obtain an estimate of net increase. Managers would then have a sound basis for predicting how many hogs of each age class would have to be removed in order to stabilize or reduce the population. Since different age classes and the two sexes are not equally important to the reproductive success of the population, the question is not only how many hogs are removed but which ones. Using a model based on age classes, a manager can judge his efficiency in terms of l_x m_x and future reproductive potential. A three year old sow may be worth five or ten piglets.

Suggested annual data collection.

A. Hogs

1. Yearly census (possibly in January, by watersheds)

2. Trapping and shooting records by season

a. Age

b. Sex

c. Condition and weight

d. Number of embryos in females

3. Records of natural mortality

4. Poacher kills (This requires asking the right people and acquiring the trust of localhunting clubs).

5. Movement into new areas, first rooting records.

B. Environment

1. Mast by tree species and elevation

2. Other foods

3. Weather (data already available)

a. Minimum temperatures

b. Monthly mean temperatures and precipatation

c. Ice storms, deep snow, and floods

C. Other species

1. Bear census (The University of Tennessee is already working on this.)

2. Ground nesting bird census (Turkeys and grouse should be easy to do and a local Audabon group might be asked to help.)

3. Other species particularly deer could be done

4. Continuation of damage surveys in different plant communities.

C. Improving the control techniques

Relegating large amounts of manpower to hog control is wasteful unless the methods used are the most efficient possible. Before launching a full scale control program the Park Service should first experiment with a variety of potential improvement in the control techniques presently in use and critically examine all possibilities.

Fox (1972) found that direct reduction was cheaper than any of the trapping techniques presently in use in the Park. These results do not, however, prove that direct reduction is cheaper than all trapping techniques. The efficiency of a trapping technique depends on several modifiable components:

(1) Placement of the trap.

(2) Bait or attractant used.

(3) Design of the trap, particularly the gate and the trap.

TRAP PLACEMENT.

As Fox (1972) notes "it would seem that methods of determining a higher probability of (hog) activity would prove very beneficial in trapping as well as direct reduction." In Fox's study of 3,325 trap nights there was hog activity near the traps on only 207 nights and there were captures on only 40 of these. This means that a conscientious manager will have to check the traps 50 to 100 times for each capture. If he could, however, place his trap where hog activity was guaranteed, he might expect a capture on one out of five nights. A knowledge of hog food habits and habitat preferences could save a majority of the man hours spent on the control program. Two attempts in this direction have already been made, those of Belden (1972) and Scott (1973). Unfortunately, neither of these studies apply directly to the Park Service problems. Belden provides a good general outline of the altitudinal movements of the hogs, but his "ocular estimates" of forest type are too vague to allow effective placement of traps.

Scott's (1973) stomach content analysis hardly mentions a genus or species[1].

A detailed survey of hog rooting in different plant communities is obviously required. The study should emphasize floristic details, the usefulness of which can be illustrated by a simple example.

In high elevation beech forest, the rooting pattern of hogs is controlled by two main factors, the composition of the herbaceous understory and the phenology of the plants. The hogs prefer a mesic beech understory composed of forbs and barely touch sites dominated by grasses and sedges. To predict where the hogs will concentrate above 4500 feet elevation, a manager needs to know not only that the canopy is composed of beech and buckeye but also that there are carpets of spring herbs like *Claytonia virginica* and *Erythronium americanum* and that the summer flora includes *Laportea*, *Angelica*, *Rudbeckia lacinata* and *Athyrium felix-femina*.

Efficient trapping can only be conducted when the hogs are present, which in beech forest, will be for about three weeks between the blooming of *Claytonia virginica* and the complete closure of the canopy. After the disappearance of the vernal flora, hog rooting drops to a low level and continues as an occasional event through the summer. There is almost no hog activity during winter and early spring. An efficient trapping or shooting program should concentrate its effort

[1]Scott's (1973) catagories of food items are usually exceedingly general like woody roots, green parts of plants or Gramineae. There is no information on where the hogs were taken. The high proportions of apples and grasses in the summer imply that many of the hogs were shot in Cades Cove and that a number of natural communities were severely undersampled. Scott's assessment of the importance of different food items may have little relation to their actual utilization by hogs. One cannot assess the importance of acorns in the hogs' diet in the fall unless the percentage of the hogs analysed which were shot in oak forest and the percent of the total hog population in oak forest at the time is known. Averaged data for the whole Park is meaningless because there are too many different habitats involved. Scott (1973) misidentified some of the few taxa he mentions. His *Urtica* sp., for instance, is almost certainly *Laportea canadensis* and his wild yam is probably *Dioscorea batatas* not D. *villosa*. Oddly, he lists Gramineae, but there is not mention of the Cyperaceae or Juncaceae which are so common in woodland situations.

in the month following the full bloom of Claytonia and then move to more productive sites. Since the density of the hogs in beech forest is very high in late spring, this is an optimal situation for trapping. Clearly, three weeks worth of intense trapping effort should offer better return than a more casual program spaced throughout the year. In the present control program traps are often moved to sites well after the rooting has started and the traps are then left long after the hogs have gone.

Locating other good trapping sites and interpreting the temporal patterns involved is a job for a plant ecologist or a general ecologist with some knowledge of plant taxonomy. Hog sign is fairly easy to recognize whereas the complex mosaic of plant communities is difficult to untangle. A field study similar to Belden's (1972), but more detailed, should be conducted. Data collection could include:

(1) Site type grazing intensity information.

Whittaker's (1956) study will provide a solid outline for classifying the plant communities. Most of his groups can be subdivided according to the species composition of the canopy and understory. Rélevé sampling for plant species should accompany estimates of rooting intensity in the communities most frequently or intensively utilized by hogs. Accurate species lists should have a high predictive value for trap placement if the exact time of hog rooting is related to flowering and fruiting times. The same survey can also serve as a record of damage to plant communities.

(2) Trap success.

Sites which are frequently utilized or intensely rooted should be recorded on topographic maps. If traps are set up or shooting is conducted, the relative success at each site should be documented. Accurate lists of the surrounding plant species should be compiled. Belden's (1972) and Fox's (1972) studies can be used as foundation for this.

(3) Collection of potential food items.

When freshly rooted sites are inspected, the investigator should sift through the remains and pick out fragments of roots, rhizomes, half-eaten insects, and any other potential food items. Frequently roots can be identified by comparison with surrounding plants. Rhizomes and tubers can be regenerated. The time of year and the condition of the plants should be noted. If a certain species is found in a high proportion of damaged sites it may be an important food item and can, in any case, serve as an indicator species for predicting hog activity.

(4) Stomach contents.

The hog stomach contents study should be redone. Not only should the site of the shooting be recorded but the forest type and plant species present should be listed. Again phenological notes about the species in bloom, in fruit or dying back can be useful. If the most important food items can be identified to species or genus, then traps can be placed in sites with an abundance of an appropriate species.

(5) Herd size.

Information on the size of herds and the density of the animals numbers in different habitats can be extracted from sightings, hog tracks and estimates of rooting intensity. Herd size should vary with season and be at a maximum during rut. Control techniques are most likely to be effective when the animals are in large groups.

Management personnel may find that conducting the control program throughout the year is not as efficient as operating only when the herds are large or a large portion of the population is gathered in a small area. Further, during late winter, when food is likely to be in short supply, hogs may be more easily attracted into heavily baited traps. In January and February, the hogs will be concentrated at the low elevations. The chances of interference from

bears and from Park visitors are much less. January is an excellant time to catch pregnant sows.

A control program which is keyed to a variety of habitats at different times of year will require moving traps frequently or using a large number of traps and deactivating part of them for long periods. It will also require a manager to coordinate the work.

BAIT

Fox (1972) indicates that one of the greatest sources of inefficiency in trapping is the capture of animals other than hogs. In a trapping sequence which resulted in 40 hog captures the traps were closed 217 times by other animals. There were 83 captures of raccoons, 6 of bear and 6 of deer. 115 times, the culprit, probably a bird or small mammal, escaped. Rather than being "hog traps", the cages collected a random assortment of whatever wildlife was in the vicinity.

As Fox (1972) mentions, the bait used for trapping in the Park is normally cracked corn, which is convenient to purchase, light to carry and easy to scatter. Unfortunately, it is attractive to a wide variety of wildlife including grouse, crows, squirrels, deer, bears and raccoons. Diurnal birds and mammals may relieve a trap of its bait long before the hogs get anywhere near it. Not only will these smaller animals sometimes trip the gate and then flee, but they can easily eat most of the bait and leave the trap open and empty.

In order to improve trapping efficiency, a more selective bait should be used. Field observations indicate that hogs can locate food several inches underground. Burying the bait will exclude crows, grouse, turkeys and deer and should slow down the raccoons. Some simple experiments with penned hogs can provide information on optimal bait sizes, depths, and patterns of dispersal.

New bait items could also improve trapping efficiency. The hogs in the Park are incredibly adept at locating patches of *Dioscorea batatas*, which implies

potatoes or yams might be good bait. Makin (1971) points to potatoes as the main source of agricultural damage by hogs; it is well known that wild boar often travel long distances, more than 10 or 15 kilometers, to raid potato fields. Tubers keep well when buried, and will remain in good condition until discovered by the hogs. The size and weight of potatoes make them difficult to transport, but the same properties make it nearly impossible for small mammals to remove them from the traps.

Some observations on the normal food habits of the wild boar may provide clues to other successful baits. The hogs preferences for certain foods at certain times of year indicate they respond to chemical changes in the plants. The hogs are best able to find the bulbs of Turk's-cap lily when the stems are dying back for the season. This implies the hogs may be able to smell the sugars involved in moving nutrients to the bulbs. Another example is found in Bromlei (1964) who mentions that hogs only eat winter horsetail in winter. Bromlei attributes this to the presence of "soluble carbohydrates" after frost. A few experiments with penned hogs on their preferences for different sugars and starches, in dry, crystalline or dissolved forms could provide a highly attractive bait that pigs can locate easily.

Aside from food, Fox (1972) experimented with using a sow in heat for bait. This use of sexual attractants for trapping hogs has potential but will require some modification. First, sows are heavy and hard to handle so, the use of a pure chemical substance isolated from the animal is desirable. This might be achieved by collecting urine or by washing the external gentilia with the right solvent after injecting the sow with hormones. If the proper volatile chemical can be gotten in solution then the whole thing can be used for bait by allowing it to slowly evaporate. Second, certain times of year are likely to be more profitable trapping with this technique than others. If, for instance, pheromones

or females in esterous and food were used together during the rutting season, when the hogs are in large herds, both males and females might be captured. When, for public relations purposes, providing hogs for stocking at Tellico or other areas seems useful, sows in esterous or pheromones might be used to round up a few males immediately before the hunts. Chemical attractants will require experimentation and probably some laboratory work.

Baits and attractants can be used in conjunction with reduction techniques other than trapping. A selective bait is necessary for administering anti-fertility agents or poisons. Baiting could also potentially improve the efficiency of direct reduction.

TRAP DESIGN

Another major limitation on the success of the present trapping program is the size of the traps employed. All of the "portable traps" are individual traps and the four group traps are permanently placed. There are no group traps throughout most of the hogs' range. Since hogs often travel in herds, the individual traps only capture a small percentage of the animals near the trap. Direct reduction also makes no use of the size of the herds.

According to Donarov and Teplov (1938), herd size may be between 1 and 40 animals. The average varies from month to month from 3.0 to 10.2 animals. The latter figure is for rutting season. The average number of wild boar in 273 individual sightings was 5.9 for the year. A corral trap should, therefore, be the most efficient. Because of the rough topography of the Southern Appalachians, the elements of a trap have to be light and easy to assemble. A variety of fencing mater including barbed wire, and electric fence could be tried. Some quick trials in the field and with penned wild hogs will provide the necessary information about fence he wire spacing, wire tension and the usefulness of electric current. Electric fence doe not always work well to exclude hogs from fields and forest plantations (Cointat 195 Used in combination with other types of fencing materials, and used with a stronger

than normal electric charge, electric fence might lower the weight of the other materials needed. Snethlage (1967) suggests two different hog proof fence designs. The first is made of mesh fencing or regular hog fence. This fence should begin at ground level and stand about a meter high. Snethlage puts a thick pole above the mesh but an electrified wire might serve the same purpose.

The second design is about the same height. Near the ground, 4 strands of barbed wire are strung 10 to 20 cm. apart. Two more strands, with slightly wider spacing (30 cm.), are strung above. The strands are then fastened together by more wire tied perpendicularly to the ground. Depressions, creating gaps under the fence where the hogs could crawl out of the enclosure, can be closed with stakes. A slat or pole placed lengthwise along the bottom of the fence will serve the same purpose.

In forests where the trees are narrow in diameter, the trunks may serve as fence posts. A piece of wood should be inserted between the wire and the tree to prevent damage to the bark. Supplemental fence posts can be used as necessary. According to Snethlage (1967) the posts or trees should not be more than 6 meters apart. The corral does not have to be regular in shape and the design should reflect local topographic patterns. Sturdiness is more important than neatness.

Since many of the best trapping areas are not easily accessible, the lighter the materials, the better. The trap has to be able to hold a mature boar, of course, but cyclone fencing is probably not necessary. If all the materials could be horse packed or back packed, traps could be constructed in areas which have the heaviest concentrations of hogs.

One of the greatest shortcomings of the group traps already in use in the Park is their failure to produce more multiple captures than the smaller portable traps. The difficulty is simply that the first animal in the trap springs the slam gate. There are several possible solutions which will require some ex-

perimentation. One possibility is a multiple trap. The animals have to knock over, a step on or uproot more than one trigger mechanism. The triggers could be set up near scattered concentrations of bait. Another possibility is a delayed action trigger. The first or second hog in the trap hits the trigger but several minutes elapse before the gate slams down. This provides time for more individuals to wander into the trap before it shuts. These techniques will require large amounts of bait in the traps to keep the hogs from eating all the bait and leaving before the trap shuts. A one way sliding gate or turnstile is also worth trying with heavily baited traps.

OTHER TECHNIQUES.

Shooting has advantages when the hogs are widely scattered, but a carefully conducted trapping program should be superior when the hogs are in herds. The success of a shooting program can be improved by using ecological data to locate concentrations of animals and by baiting. Driving or using dogs can also increase the number of encounters in direct reduction.

Poisoning or sterilizing with chemical agents requires extremely specific baits. Although both techniques are worth considering, they will require a more extensive food habits study than is presently available.

PHILOSOPHICAL PROBLEMS.

Some of the most severe limitations on the Control Program are neither technical nor scientific, but are a function of the point of view from which the work is conducted. Almost all the hog trapping has been done along jeep roads, for instance. Unfortunately, many of the smaller watersheds can only be reached on foot or horseback and many of the best potential trapping sites are more than half a mile from the nearest road. Although there are good reasons for conducting intensive control around Cades Cove where the traps are easy to check,

some of the work will have to be done in the back country, out on the ridges and down in the valleys without access roads.

Since there are more problems on the highways and in the campgrounds than the staff can handle, the back country ranger and pack horse have all but disappeared in the Great Smoky Mountains. The hogs have to be met on their own ground, however, and the problem is not concentrated in convenient places. The "inaccessibility" of the back country is the usual reason given for restricting trapping to sites near roads, but the difficulty can be overcome by hiking, horseback riding, packing heavy equipment, working long days and staying out all night on the trail.

A second similar limitation on the control program is the lack of biological staff in the Park. Most of what little scientific work is being done in the Park is falling into a vaccuum. Central coordination of projects is lacking and a majority of the data obtained is never used. The ranger in charge of management has too many other responsibilities, such as fire control, to devote any time to building an effective research program. The present situation is wasting time and resources. The Park Service needs to establish a better bridge between research and management.

The Park now has a number of chronic ecological problems, such as the hogs and the accelerating woody plant invasion of the grass balds. Eventually something will have to be done since these afflictions show no signs of healing themselves. The Park has considered making room for a biologist but has put off actually getting one. In the meantime, wildflower areas are being severely damaged, and the hog problem is spreading to include the whole Park. In fact, the hog population is now large enough so that it is unlikely one or two additional staff members will be able to bring the species under control. A biologist could actually be most useful in soliciting and coordinating help from outside agencies and universities.

The question is essentially one of land stewardship and a sense of responsibility for the native flora and faura. The Park needs ecological watchmen who will recognize and solve the problems as they arise.

III. Conclusion.

The Park Service needs to take a new direction in ecological management in Great Smoky Mountains National Park. The European wild boar population has caused extensive damage and is now large enough to warrant full time attention from the management staff. Even if various universities and graduate students assist in the project, central coordination must come from within the Park. It may already be impossible to exterminate the wild boar within the Park, but this should not become an excuse for abandoning control altogether. In order to protect the native flora and fauna the hog population has to be kept low and stable. If the boar are allowed free run of the Park they will surely take it.

An efficient control program cannot be disconnected from natural history and basic ecologic research. A good field ecologist or wildlife manager will, of course, realize immediately that most of the necessary information on life history casually mentioned in this paper can be extremely difficult to obtain. In spite of this the Europeans have gathered volumes of relevant population data and there is no reason to believe, that the same thing cannot be accomplished in the Smokies. It is a matter of time, money, and most important, finding the right people to do the work.

The control program must favor imagination and experimentation until more efficient methods of hog control are developed. The suggestions presented in this paper are not offered as a final solution but instead are to be treated as ideas which can be tried and evaluated. If they prove impractical or inefficient they should be modified, or abandoned and replaced by something better.

Effective management must be dynamic, bending and adjusting to each idiosyncrasy of each species concerned. Park policies have to evolve with changes in the

populations and the intensity of the disturbance. None of the Park's present management problems have easy or clear cut solutions, but none of them are completely insoluble. I am convinced that most of the difficulties can be resolved by hard work, good science, and common sense.

LITERATURE CITED

Beeman, Larry Eugene. 1971. Seasonal food habits of the black bear (*Ursus americanus*) in the Smoky Mountains of Tennessee and North Carolina. M.S. Thesis. The University of Tennessee. 62 pp.

Belden, R.C. 1972. Rooting and wallowing activities of the European Wild Hog (*Sus scrofa*) in the mountains of East Tennessee. M.S. Thesis. The University of Tennessee. 68 pp.

Bjerke, S. 1957. Nogle traek af de sydskandinaviske lovskoves udujkling gennem de sidste arhundreder. Dansk dendrol. Arsskv. No. 4 :373-413.

Bjerke, S. 1959. Om svin og skov. Dansk skovforen. Tidsskr. 44(10): 529-40.

Boback, A.W. 1957. Das Schwarzwild. Neumann Verlag: Leipzig. 141 pp.

Bratton, S.P. 1974. The effect of the European Wild Boar (*Sus scrofa* L.) on the high-elevation vernal flora in Great Smoky Mountains National Park. Manuscript. Cornell

University. 30 pp.

Briedermann, L. 1967. Die Náhrungs Komponenten des Schwarzwildes (Sus s. scrofa 1959) in der Mitteleuropaischen Kulturlandschaft. Trans. of the VIIth Congr. of the Inter. Union of Game Biologists: 207-213.

Briedermann, L. 1968. Die biologische und forstliche Bedeutung des Wildschweines in Wirtschaftswald. Arch. Forstwes. 17(9):943-967.

Bromlei, G.F. 1964. Ussuriiskii Kaban. Izdatel'stuo "Nauka", Moskva. 107 pp.

Cabon, K. 1957. Das Massensterben von Wildschweinen im Naturstaatspark von Bialowiezc im Winter 1955/56. Acta Theriol., Bialowiezc 2(4): 71-82.

Campbell, C.C., W.F. Hutson and A.J. Sharp. 1962. Great Smoky Mountains Wildflowers. The University of Tennessee Press, Knoxville. 112 pp.

Cointat, M. 1953. Cloture electrique en foret. Rev. For. Franc. 5(11): 15-16.

Conley, R.H., V.G. Henry and G.H. Matchke. 1972. European Hog Research Project W-34. Tennessee Game and Fish Commission. Nashville. 259 pp.

Donaurov, S.S. and V.P. Teplov. 1938. Kaban v Kavkazskom Zapovednike. Trudy Kabkazskogo Gosudarstvennogo Zapovednika. 1:191-226.

Fadeev, E.V. 1973. Dinamika chslennosti kabana (Sus scrofa) V Evropeiskoi Rossii. Zool. Zh. 52(8): 1214-1219.

Fernald, Merritt Syndon. 1950. Gray's Manual of Botany: Eigth (Centenial) Edition. American Book Company: New York 1632 pp.

Fox, J.R. 1972. An evaluation of control techniques for the European Wild Hog (Sus scrofa) in the Great Smoky Mountains National Park of Tennessee. M.S. Thesis. The University of Tennessee. 76 pp.

Gavrin, V.F. and C.C. Donaurov. 1954. Volk v Belovezhskoi Pushche. Zool. Zh. 36(4):904-924.

Haber, A. 1961. Le sanglier en Pologne. Terre et Vie. 108:74-76.

Hennig, R. 1963. Schwarzwildhege, Schwarzwildjagd. Landbuch-Verlag GMBH, Hanover. 116 pp.

Hennig, R. 1972. Das Schwarzwild. Landbuch-Verlag GMBH, Hannover. 68 pp.

Henry, V.G. and R.H. Conley. 1972. Fall foods of the European Wild Hogs in the Southern Appalachins. J. Wildl. Mgmt. 36(3):854-860.

Heptner, V.G. and N.P. Naumov. 1966. Die Saugetiere der Sowjetunion. VEB Gustav Fischer Verlag, Jena. 939 pp.

Hoffman, Harold L. 1962. Check list of vascular plants of the Great Smoky Mountains. Castanea 29:1-45.

Janda, M. 1958. Die Nahrung des Schwarzwildes Im Mittelgebirgsgebiet von Stiavnica. Saugetier Kundl. Mitt. 4(2):67-72.

Kerschagl, W. 1965. Wildkrankheiten. Osterreichischer Jagd - und Fischerei-Verlag des N-O. Landesjagdverbandes, Wien. 328 pp.

Kormilitsin, A.A. and A.I. Dulitsii. 1972. K

reakklimatizatsii suin'i dikoi (*Sus scrofa* L.) v Krymu. Vestnik Zoologii: 6 (1):38-44.

Kozlo, P.G. 1970. Faktory, opredelyayushchie dinamiku chislennosti Kabana (*Sus scrofa*) V Belovezhskoi Pushche. Zool. Zh. 49: 422-430.

Linzey, A.V. and D.W. Linzey. 1971. Mammals of Great Smoky Mountains National Park. The University of Tennessee Press, Knoxville. 114 pp.

Loginov, V.V. 1936. Novye dannye k poznaniyu biologii Kaukazskogo Kaban (*Sus scrofa attila* Thomas). Bull. Soc. Nat. Moscow, Sect. Biol. 45:10-21.

Mackin, R. 1970. Dynamics of Damage caused by wild boar to different agriculture crops. Acta Theriologica. 15(27):447-458.

Matschke, G.H. 1967 (1964). The influence of oak mast on European wild hog reproduction. Proc. Southeastern Assoc. Game and Fish Commissioners Conf. 18: 35-39.

Muller-Using, D. 1960. Grobtier und Kulturlandschaft im mitteleuropaischen Raum. Musterschmidt Verlag: Gottingen. 157 pp.

Niethammer, G. 1963. Die Einburgerung von Saugentieren und Voglen in Europa. Verlag Paul Parey. Hamburg 319 pp.

Peterson, R.T. and M. McKenny. 1968. A Field Guide to Wildflowers of Northeastern and North-central North America. Houghton Mifflin Co., Boston. 420 pp.

Pfeffer, P. 1961. L'ecologie du sanglier en Asie centrale d'Apres les recherches d'A.A. Sloudsky. Terre et Vie. 108: 368-372.

Radford, A.E., H.E. Ahles, and C.R. Bell. 1968. Manual of the Vascular Flora of the Carolinas. The University of North Carolina Press. Chapel Hill. 1183 pp.

Rakov, N.V. 1966. Ob osobennostyakh sosushchestvovaniya Kaban, burogo i chepnogo medvedei v Amuro - Ussuriiskom Krae. Zool. Zh. 45(4):617-618.

Rakov, N.V. 1970. O fakorakh smertnosti kabana i ego vzaimootnosheniyakh S Khshchnikami v Priamur'e. Zool. Zh. 49(8): 1220-1228.

Sablina, T.B. 1955. Kopytnye Belovezhskoi Pushchi.

Akademiia Nauk SRR. Institut Morfologii Zhivotnykh. 15:1-191.

Schulze. 1965. Die Krankheiten des Wildes. F.C. Mayer Verlag. Munchen Solln. 214 pp.

Scott, C.D. 1973. Seasonal food habits of European wild hogs (Sus scrofa) in the Great Smoky Mountains National Park. M.S. Thesis. University of Tennessee, 54 pp.

Severtsov, S.A. and T.B. Sablina. 1953. Olen', kosulya i kaban v Zapovedhike Belovezhskaya Pushcha. Akademiia Nauk SSSR. Institut Morfologii Zhivotnykh. 9:140-205.

Sludskii, A.A. 1956. Kaban: Morfologiya, Ekologiya, Khozyaistvennoe i Epizootologicheskoe Znachenie, Promysel. Izdatel'svo Akademii Nauk Kazakhskoi SSR, Alma-Ata. 219 pp.

Snethlage, K. 1967. Das Schwarzwild. Verlag Paul Pareg, Hamburg. 215 pp.

Snethlage, K and K.H. Snethlage. 1966. Schwarzwildfibel. Verlag Paul Parey, Hamburg. 29 pp.

Spiecker, von. D. 1969. Verlauf und Ausbreitung der Schweinepest (Pesti suum) in der Eifel in den Jahren 1963 und

1964. Z. Jagdwiss. 15: 144-151.

Stegeman, L.C. 1938. The European wild boar in the Cherokee National Forest, Tennessee. J. Mammal. 19(3):279-290.

Stupka, Arthur. 1960. Great Smoky Mountains National Park, Natural History Handbook, Series No. 5. U.S. Government Printing Office, Washington, D.C. 75 pp.

Stupka, A. 1963. Notes on the Birds of Great Smoky Mountains National Park. The University of Tennessee Press, Knoxville. 242 pp.

Vereshchagin, N.K. 1967. The Mammals of the Caucasus: A History of the Evolution of the Fauna. U.S. Department of Commerce. Springfield, Va. 816 pp.

Weidenmuller, H. 1964. Fibel der Wild Krankheiten. Verlag Eugen Ulmer. Stuttgart. 116 pp.

Wetzel, R. and W. Rieck. 1962. Krankheiten des Wildes. Verlag Paul Parey, Hamburg. 224 pp.

Whittaker, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecol. Monogr. 26:1-80.

Williamson, M.J. and M.R. Pelton. 1971. New design for a large portable mammal trap. Trans. Ann. Conf. SE Assoc. of Game and Fish Comm. 25: 315-322.

ADDITIONAL REFERENCES

General:

Severtsov, S. A. and T. B. Sablina, 1953. Olen', Kosulya Kabum V. Zapoveduite Belovezhskaya Pushcha. Izdatel'svo Akademiaa Nauk SSSR. Institute Morfologii Zhivotuykl, 9:140-205.

Jones, Perry. 1972. The European wild boar in North Carolina. North Carolina Wildlife Resources Commission. Raleigh, N.C. 27 pp.

Pine, D.S. and G.L. Gerdes. 1973. Wild pigs in Monterey County, California. California Fish and Game 59(2): 126-137.

Haber, A. 1969 Dzik. Panstwowe Wydawnicto Rolnicze i Lesne. Waszawa. 216 pp.

Oloff, H. 1951. Zur Biologie and Okologie des Wildschweines. Beitrage zur Tierkunde and Tierzucht. Band 2. 95 pp.

Rakov, N.V. 1956. Nekotorye osobennosti uslobpv sushchectvovanpya kabana na Spkhote-Aline. Biolleten M. O-va. Isp. Pripody, Otd. Biologii. T. LXI (1) 13 22.

Hanson, R. P. and L. Karstad. 1959. Feral swine in the southeastern United States. J. Wildl. Mgmt. 23(1):64-75.

Shaw, A.C. 1941. The European wild hog in America. Trans. N. Amer. Wildl. Conf. 5:436-441.

Behavior:

Fradrich, H. 1974. A comparison of behavior in the Suidae. In The Behavior of Ungulates and Its Relation to Management. pp. 133-143.

Fradrich, H. 1967. Das Verhalten der Schweine (Suidae, Tasassuidae) and Flusspferde (Hippopotamidae). Hdb. d. Zool. 10(26):1-44.

Briedermann, L. 1973 Ermittlungen zur Aktivitatsperiodik des Mitteleuropasschen Wildschweines. Zool. Garten i. Dr. b.

Damage and food habits:

Spatz, G. and D. Mueller-Dombois. 1972. Succession patterns after pig digging in grassland communities on Mauna Loa, Hawaii. Island Ecosystems IBP, Technical Report No. 15. 44 pp.

Zappe, E. 1958. Bedeutung des Schwarzwildes Schadinsektengradation in Walde. Forst and Jagd 8: 33-34.

Krammer, R. J. 1971. Hawaii Land Mammals. Charles E. Tuttle Co., Rutland, Vermont. 347 pp. (see chapter on pig food habits).

Henry, V. G. Predation on dummy nests of ground nesting birds in the Southern Appalachians. J. Wildl. Manage. 33(1):169-172.

Matschke, G. H. 1965. Predation by European wild hogs on dummy nests of ground-dwelling birds. Trans. Ann. Conf. S.E. Assoc. of Game and Fish Comm. 20:74-84.

Matschke, G. H. 1964. The influence of oak mast on European wild hog production. Trans. Ann. Conf. S.E. Association Game and Fish Comm. 19:154-156.

Matschke, G. H., K. M. Barht and R. L. Murphree. 1973. Digestion of crude protein in white oak acorns by European wild hogs and Pitman-Moore minature hogs. · J. Tenn. Acad. Sci. 48(3): 85-86.

Bratton, S.P. 1975. The effect the European wild boar on Gray Beech Forest in the Great Smoky Mountains. Ecology 56(6).

Howe, T. and S. P. Bratton. Manuscript. Winter rooting activity of the European wild boar..18 pp.

Wodzicki, K. A. Introduced Mammals of New Zealand. Department of Scientific and Industrial Research Bulletin No. 98 (see pages 227 to 240).

Howard, W. E. 1964. Introduced browsing mammals and habitat stability in New Zealand. J. Wildl. Manage. 28(3): 421-430.

Management:

Taber, R. 1961. Wildlife administration and management in Poland. J. Wildl. Manage. 25(4):353-363.

Webb, W. L. 1960. Forest wildlife management in Germany. J. Wildl. Manage. 24(2):147-161.

Zurowski, W. and M. Sakowicz. 1965. Effects of succinylcholine chloride on wild boars. J. Wildl. Manage. 29(3):626-629.

Henry, V. G. and G. H. Matschke. 1968. Immobilizing trapped European wild hogs with Cap- Chur-Barb. J. Wildl. Manage. 32(4):970-972.

Matschke, G. H. 1962. Trapping and handling European wild hogs. Trans. Ann. Conf. S. E. Assoc. of Game and Fish Comm. 16:21-24.

Matschke, G. H. and V. G. Henry. 1969. Immobilizing European wild hogs with succinylcholine chloride. J. Wildl. Manage. 33(4):1039-1041.

Munzel, E. 1971. Der Saupark bei Springe. Stuttgart:DRW-Verlag. 147 pp.

Henry, V. G. 1966. European wild hog hunting season recommendations based on reproductive data. Trans. Ann. Conf. S.E. Assoc. of Game and Fish Comm. 20:139-145.

Movements:

Kurz, C. J. and P. L. Marchinton. 1972. Radiotelemetry studies of feral hogs in South Carolina. J. Wildl. Manage. 36(4):1240-1250.

Matschke, G. H. and J. P. Hardister. 1966. Movement of transplanted European wild boars in North Carolina and Tennessee. Trans. Ann. Conf. S.E. Assoc. of Game and Fish Comm. 20:74-84.

Fadeev, E. V. 1970. Estestbennoe i iskusstvennoe rasselenie kabana v Evropeiskoi chasti RSFSR. Biologicheskie Nauki 1:28-34.

Fadeev, E. V. 1973. K ekologii kabana tsentralnoi Rossii. Vest. Mosk. Univer. Biol. 5:20-28.

Chernjavskaya, S. I. 1956. Sezonne rasmeshchenie i kochevki dikikh kopynykh i medvedya b raione Kavkazskogo Zapovednika v svyazi s raspredeleniem urozhaya plodov fruktarnikov i orekhonosov. Biol. M. O-VA Isp. Prirody, Otd. Biologii. LXI(4):7-21.

Nasimovich, A. A. 1955. Rol Rezhima Snezhogo Iokpova V Zhizni Kopytnykh Zhivotnykh na Territorii SSSR. Izdatelstvo Akademii Hauk SSR. Mosckva. (Chapter on wild boar 288-297).

Morphology and reproduction:

Briedermann, Lutz. 1970. Zum Korper - and Organwachstum des Wildschweines in der Deutschen Demokratischen Republik. Arch. Forstwes. 19(4):401-420.

Briedermann, Lutz. 1971. Zur Reproduction des Schwarzwildes in der Deutschen Demokratischen Republik. Tag. Ber. dt. Akad. Landwirtsch. 113:169-186.

Cabon, K. 1959. Problem der Alterbestimmung beim Wildschwein (Sus scrofa L.) nach der Methode von Dub. Acta Theriol. 3(8):113-124.

Cabon, K. 1958. Untersuchungen uber die Schadelvariabilitat des Wildschweines, Sus scrofa L. aus Nordostpolen. Acta Theriol. 2(6):107-139.

Duncan, R. W. 1974. Reproductive biology of the European wild hog (Sus scrofa) in the Great Smoky Mountains of Tennessee. M. S. Thesis, University of Tennessee, Knoxville. 95 pp.

Henson, T. M. 1975. Age determination and age structure of the European wild hog (Sus scrofa). M. S. Thesis, University of Tennessee, Knoxville. 58 pp.

Henry, V. G. 1968. Length of the estrous cycle and gestation in European wild hogs. J. Wildl. Manage. 32(2):406-408.

Henry, V. G. 1968. Fetal development in European wild hogs, J. Wildl. Manage. 32(4):966-970.

Henry, V. G. 1969. Estimating whole weights from dresses weights for European wild hogs. J. Wildl. Manage. 33(1):22-225.

Henry, V. G. 1969. Detecting the presence of European wild hogs. J. Tenn. Acad. Sci. 44(4):20-23.

Matschke, G. H. 1963. An eye lens-nutrition study of penned European wild hogs. Trans. Ann. Conf. S.E. Assoc. of Game and Fish Comm. 17:20-27.

Matschke, G. H. 1967. Aging European wild hogs by dentition. J. Wildl. Manage. 31(1):109-113.

Morphology continued:

Williamson, M. J. 1972. Some hematological and serum biochemical parameters of European wild hogs (*Sus scrofa*). M. S. Thesis, University of Tennessee, Knoxville. 44 pp.

Da

~~SEP 16~~

FEB 19

Bratton
An integrated ecological approach to the management of the European wild boar in the GSMNP.
(Man Report no.3)

LIBRARY
GREAT SMOKY MOUNTAINS
NATIONAL PARK